

WHAT IS CLAIMED IS:

- 1 1. A substrate processing chamber comprising:
2 a chamber body;
3 a chamber top disposed on the chamber body; and
4 a transformer-coupled plasma generator plate within the substrate
5 processing chamber having a plurality of transformer cores within the transformer-
6 coupled plasma generator plate and a plurality of through holes forming conduits from
7 a first side of the transformer-coupled plasma generator plate to a second side of the
8 transformer-coupled plasma generator plate, a first conduit passing through a first
9 transformer core.
- 1 2. The substrate processing chamber of claim 1 further comprising
2 a second conduit not passing through a transformer core.
- 1 3. The substrate processing chamber of claim 1 wherein the plasma
2 generator plate is flat.
- 1 4. The substrate processing chamber of claim 1 further comprising
2 a second transformer core within the transformer-coupled plasma generating plate, a
3 first primary coil being disposed to electro-magnetically couple to the first transformer
4 core and a second primary coil being disposed to electro-magnetically couple to the
5 second transformer core, wherein the first primary coil and the second primary coil are
6 connected to each other in series.
- 1 5. The substrate processing chamber of claim 1 wherein the toroidal
2 transformer core comprises ferrite material.
- 1 6. The substrate processing chamber of claim 1 wherein the
2 transformer-coupled plasma generator plate includes a dielectric spacer between the
3 first side and the second side, and a remainder of an outer surface of the generator plate
4 comprises an electrical conductor.
- 1 7. The substrate processing chamber of claim 6 wherein the
2 dielectric spacer is disposed within a conduit through the transformer-coupled generator
3 plate.

1 8. The substrate processing chamber of claim 1 further comprising
2 an alternating-current power supply configured to operate at a frequency of about
3 1 KHz-2 MHz.

1 9. A substrate processing chamber comprising:
2 a chamber body;
3 a chamber top disposed on the chamber body;
4 an alternating-current power supply; and
5 a transformer-coupled plasma generator plate having a plurality of
6 through holes forming conduits from a first side of the transformer-coupled plasma
7 generator plate within the substrate processing chamber to a second side of the
8 transformer-coupled plasma generator plate within the substrate processing chamber, a
9 first portion of the conduits passing through centers of a plurality of toroidal
10 transformer cores within the generator plate and a second portion of the conduits not
11 passing through centers of transformer cores, the generator having a first surface
12 comprising metal, a second surface comprising metal, and a plurality of dielectric
13 spacers disposed between the first surface and the second surface in each of the first
14 portion of the conduits.

1 10. A plasma generator plate comprising:
2 a first side;
3 a second side;
4 a first conduit passing from the first side to the second side through a
5 first transformer core within the plasma generator plate;
6 a second conduit passing from the first side to the second side through a
7 second transformer core.

1 11. The plasma generator plate of claim 10 further comprising a first
2 dielectric spacer in a first secondary current path around the first transformer core.

1 12. A method of processing a substrate in a plasma processing
2 system, the method comprising:
3 providing a substrate to a substrate holder in a processing chamber of the
4 plasma processing system;

5 flowing a plasma precursor into a multi-core transformer-coupled
6 plasma generator;
7 generating a plasma from the plasma precursor with the multi-core
8 transformer coupled plasma generator; and
9 processing the substrate.

1 13. The method of claim 12 wherein the multi-core transformer-
2 coupled plasma generator is within the processing chamber.

1 14. The method of claim 13 wherein the multi-core transformer-
2 coupled plasma generator is a generator plate comprising a plurality of transformer
3 cores within the generator plate and a plurality of through-holes forming conduits from
4 a first side of the generator plate to a second side of the generator plate.

1 15. The method of claim 12 wherein plasma formed by the multi-
2 core transformer-coupled plasma generator is coupled to the processing chamber
3 through a conduit.

1 16. The method of claim 15 wherein the multi-core transformer-
2 coupled plasma generator has a first conduit passing through a first transformer core
3 and through a second transformer core.

1 17. The method of claim 15 wherein the multi-core transformer-
2 coupled plasma generator has a first conduit passing through a first transformer core
3 and a second conduit passing through a second transformer core.

1 18. A plasma processing system comprising:
2 a first substrate support structure configured to hold a first substrate in a
3 processing chamber;
4 a second substrate support structure configured to hold a second
5 substrate in the processing chamber; and
6 a transformer-coupled plasma generator within the processing chamber
7 disposed between the first substrate support structure and the second substrate support
8 structure.

1 19. The plasma processing system of claim 18 wherein the
2 transformer-coupled plasma generator includes a toroidal transformer core.

1 20. The plasma processing system of claim 18 wherein the plasma
2 generator comprises a plasma generating plate having a plurality of transformer cores
3 within the plasma generating plate and a plurality of through holes forming conduits
4 from a first side of the plate to a second side of the plate.

1 21. A method of simultaneously processing substrates in a plasma
2 processing system, the method comprising:
3 providing a first wafer and a second wafer to a processing chamber;
4 flowing plasma precursor into the chamber;
5 generating a plasma with a transformer-coupled plasma generator
6 disposed between the first wafer and the second wafer; and
7 simultaneously processing the first wafer and the second wafer.

1 22. A plasma generator comprising:
2 an inlet in fluid communication with;
3 a first conduit passing through
4 a first toroidal transformer core and through
5 a second toroidal transformer core;
6 a second conduit completing a plasma current circuit, in cooperation
7 with the first conduit, around the first toroidal transformer core and around the second
8 toroidal transformer core; and
9 an outlet in fluid communication with the first conduit.

1 23. A plasma generator comprising:
2 an inlet in fluid communication with
3 a first conduit passing through a first transformer core and with
4 a second conduit passing through a second transformer core;
5 a third conduit in fluid communication with the first conduit to complete
6 a first plasma current circuit around the first transformer and in fluid communication
7 with the second conduit to complete a second plasma current circuit around the second
8 transformer; and

9 an outlet in fluid communication with at least the first conduit and the
10 second conduit.

1 24. A substrate processing system comprising:
2 a process chamber with a chamber inlet;
3 a chamber exhaust; and
4 a transformer-coupled plasma generator having a first core,
5 a first conduit passing through the first core,
6 a second core,
7 a second conduit passing through the second core, and
8 a third conduit in fluid communication with the first conduit and
9 the second conduit to complete a plasma current circuit path through the process
10 chamber.

1 25. The substrate processing system of claim 24 wherein the third
2 conduit is a center conduit completing a first plasma current circuit path around the first
3 core through the process chamber and the first conduit and completing a second plasma
4 current circuit path around the second core through the process chamber and the second
5 conduit.

1 26. The substrate processing system of claim 24 wherein the first
2 conduit and the second conduit comprise metal and further comprising a dielectric
3 spacer in the plasma current circuit path.

1 27. The substrate processing system of claim 24 further comprising:
2 a fourth conduit passing through
3 a third core; and
4 a fifth conduit passing through
5 a fourth core.

1 28. The substrate processing system of claim 24 further comprising:
2 a first primary coil disposed to couple electro-magnetic energy to the
3 first core;
4 a second primary coil disposed to couple electro-magnetic energy to the
5 second core;

6 a third primary coil disposed to couple electro-magnetic energy to the
7 third core;
8 a fourth primary coil disposed to couple electro-magnetic energy to the
9 fourth core, wherein the first primary coil, the second primary coil, the third primary
10 coil, and the forth primary coil are coupled to an AC power supply.

1 29. The substrate processing system of claim 28 wherein the first
2 primary coil, the second primary coil, the third primary coil, and the fourth primary coil
3 are connected in series with the AC power supply.

1 30. The substrate processing system of claim 28 wherein the first
2 primary coil, the second primary coil, the third primary coil, and the fourth primary coil
3 are connected in parallel to the AC power supply.

1 31. A plasma generator comprising:
2 an inlet configured to receive a plasma precursor, the inlet in fluid
3 communication with a first plasma current path and with a second plasma current path;
4 a first conduit passing through
5 a first transformer core;
6 a second conduit passing through
7 a second transformer core, wherein the first conduit is essentially co-
8 linear with the second conduit.

1 32. A plasma generator comprising:
2 an outer shell surrounding a first inner shell housing a first toroidal
3 transformer core; and
4 a second inner shell housing a second toroidal transformer core, wherein
5 the first toroidal transformer core and the second toroidal transformer core are disposed
6 along a common center axis.

1 33. The plasma generator of claim 32 wherein the first inner shell is
2 supported within the outer shell by a web allowing circulation of secondary plasma
3 current around the first inner shell within the outer shell.

1 34. The plasma generator of claim 33 wherein the web contains an
2 electrical lead connected to a primary coil disposed to couple electro-magnetic energy
3 to the first toroidal transformer core.

1 35. The plasma generator of claim 32 wherein the first inner shell
2 includes a shaped bottom portion to provide a circular cross-section to the inner shell.

1 36. The plasma generator of claim 32 further comprising:
2 an inlet; and
3 an outlet, both the inlet and the outlet lying along the common center
4 axis.

1 37. An ion implantation system comprising:
2 an ion source having a toroidal plasma generator, and
3 an ion source aperture aligned essentially along a center line of the
4 toroidal plasma generator.

1 38. The ion implantation system of claim 37 further comprising a
2 first extraction electrode disposed to accelerate ions from the ion source toward a
3 second extraction electrode.

1 39. The ion implantation system of claim 37 wherein the toroidal
2 plasma generator includes a first core and a second core, the first core and the second
3 core being aligned essentially along a center line of the toroidal plasma generator.

1 40. A method of providing ions to an ion implantation system, the
2 method comprising:
3 providing an ion precursor to a transformer-coupled toroidal plasma
4 generator in an ion source;
5 ionizing at least a portion of the ion precursor into ions, the ions having
6 a greater density at a center of the transformer-coupled toroidal plasma generator and
7 extending along a line through the center of the transformer-coupled toroidal plasma
8 generator; and
9 ejecting a portion of the ions out of the ion source.

1 41. A plasma torch head comprising:
2 an outer nozzle;
3 an inner nozzle, the inner nozzle including a conduit passing through the
4 inner nozzle from an inlet side toward an outlet,
5 a toroidal transformer core surrounding the conduit; and
6 a bypass providing a return path for a secondary plasma current circuit
7 around the toroidal transformer core.

1 42. The plasma torch head of claim 41 wherein the inner nozzle
2 comprises metal and further including a dielectric spacer in the inner nozzle to prevent
3 an electric path through the inner nozzle around the toroidal transformer core.

1 43. The plasma torch head of claim 41 wherein a first gas is flown
2 through the conduit and a second gas is flown through the bypass, the first gas being
3 different from the second gas.

1 44. The plasma torch head of claim 43 wherein the first gas is
2 oxygen and the second gas is either propane or hydrogen.

1 45. The plasma torch head of claim 41 further comprising a primary
2 coil disposed to couple electro-magnetic energy to the toroidal transformer core
3 wherein the primary coil and the toroidal transformer core are enclosed within the inner
4 nozzle.

1 46. A method of cutting material using a plasma torch, the method
2 comprising:
3 flowing a plasma precursor in a conduit through a center of a toroidal
4 transformer core of a plasma generator in an inner nozzle of a plasma torch;
5 forming plasma from the plasma precursor;
6 completing a plasma current secondary circuit around the toroidal
7 transformer core through a bypass; and
8 transporting plasma out an outlet of the plasma torch.

1 47. The method of claim 46 further comprising flowing carrier gas
2 through the bypass.

1 48. The method of claim 46 wherein the forming plasma step
2 includes providing a primary voltage to a primary coil coupling electro-magnetic
3 energy to the toroidal transformer core, the primary voltage being an alternating-current
4 voltage less than about 115 Volts.

1 49. An ion source for an ion milling apparatus, the ion source
2 comprising:
3 a transformer-coupled toroidal plasma generator (having a primary coil
4 disposed to couple electro-magnetic energy to a toroidal core, the transformer-coupled
5 toroidal plasma generator disposed to provide plasma along a center line of the
6 transformer-coupled toroidal plasma generator toward an accelerator plate.

1 50. The ion source of claim 1 wherein the transformer-coupled
2 toroidal plasma generator further includes a second toroidal core.

1 51. A method for providing ions to an ion milling apparatus, the
2 method comprising:
3 providing an ion precursor to a transformer-coupled toroidal plasma
4 generator;
5 ionizing at least a portion of the ion precursor to form ions, the ions
6 being concentrated along a center axis of the transformer-coupled toroidal plasma
7 generator; and
8 ejection a portion of the ions toward an accelerator plate.

1 52. The method of claim 51 wherein the ion precursor forms reactive
2 ions.